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A PROGRAM GUIDE TO AUTOMATED INSTRUMENTATION FOR WATER POLLUTION SURVEILLANCE

Federal Water Pollution Control Administration
Cincinnati, Ohio

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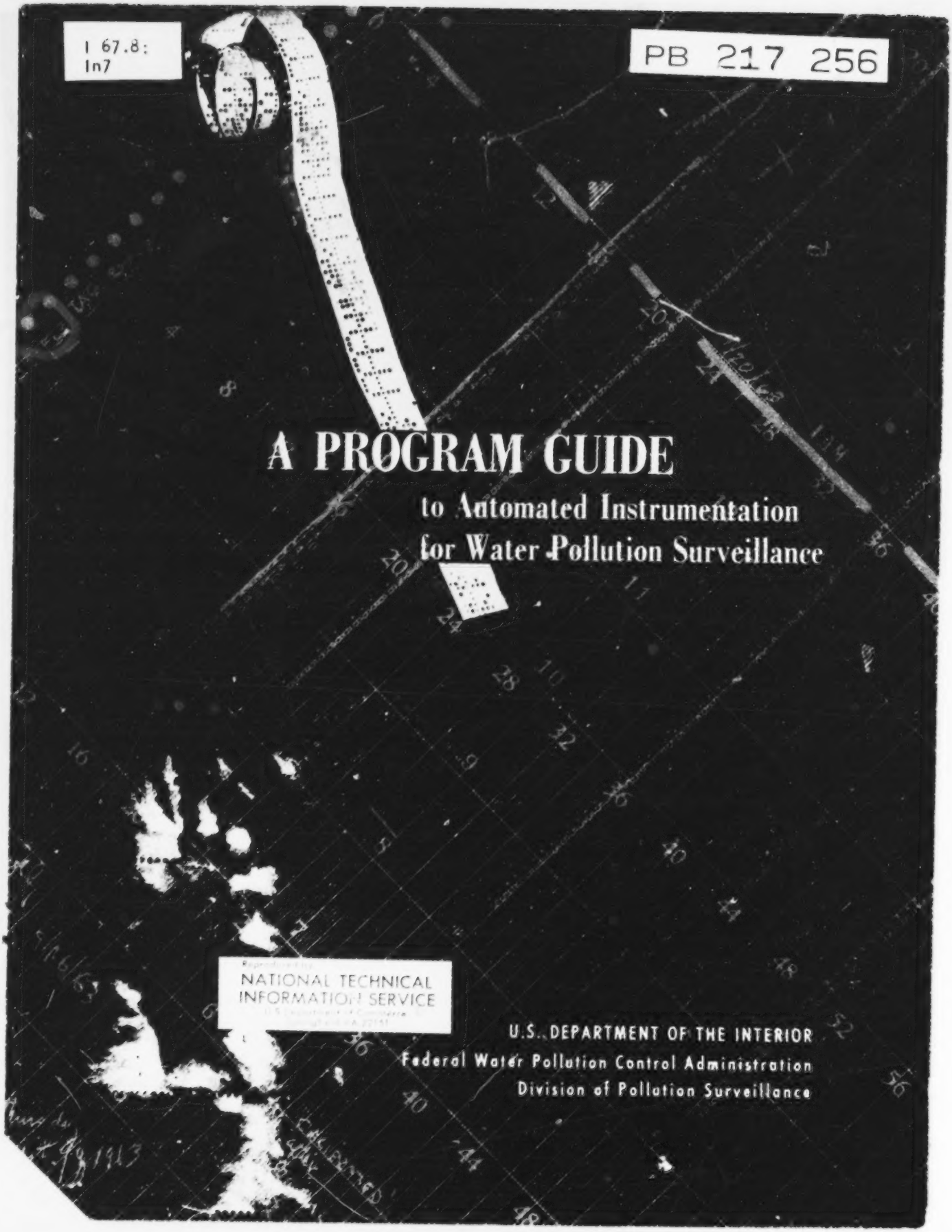

A PROGRAM GUIDE

to Automated Instrumentation for Water Pollution Surveillance

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U.S. DEPARTMENT OF THE INTERIOR
Federal Water Pollution Control Administration
Division of Pollution Surveillance

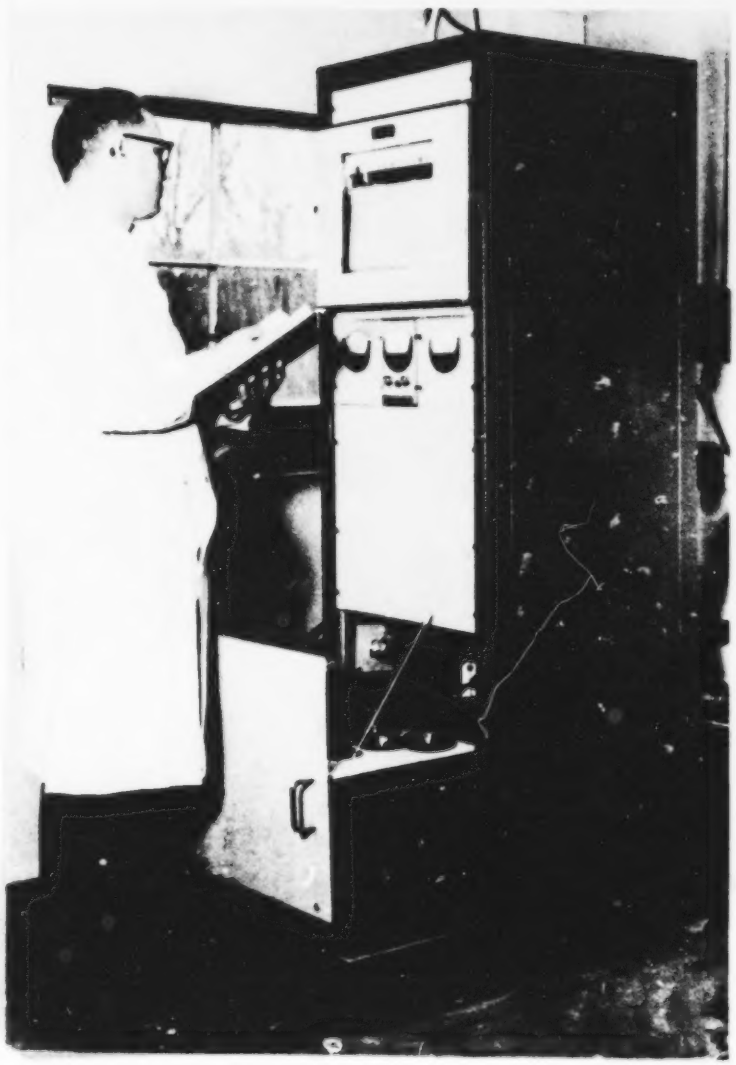

Figure 1. Automatic water quality data-collection system is evaluated at Field Test Station on the Little Miami River, Ohio.

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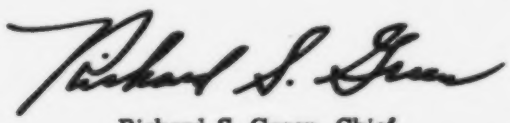
Foreword

The Federal Water Pollution Control Administration of the Department of the Interior is interested in the continuing improvement of instrumentation for the acquisition, transmission, storage, and analysis of water quality data. The Administration's Division of Pollution Surveillance has provided specialized skills and resources, based in Cincinnati Ohio, for equipment and instrumentation development. The material presented in this Program Guide is intended for the guidance of personnel engaged in water resources management, pollution surveillance, and special water quality studies.

For information on instrumentation for specific needs, write to the Regional Director, Federal Water Pollution Control Administration, at the appropriate address given on the inside back cover.



Richard S. Green, Chief
Division of Pollution Surveillance

October 1968

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Development and Use of Instrumentation

The development and use of instrumentation for the measurement of water quality and surveillance of water pollution is proceeding at an accelerated pace.[1, 2, 3, 4, 5, 6] It is important that potential users know about the fundamental principles involved in the use of such equipment and other factors to be considered before making a decision to purchase.[7, 8, 9] To assure effective use of instrumentation systems for collection of water quality data from rivers, lakes, reservoirs, estuaries, and other surface waters, the selection of parameters, determination of the amount and accuracy of data needed, and decision as to how the data will be employed should be made during the planning phase, when the program objectives are being established.

The following text presents information and illustrations* of selected available equipment ranging from portable survey devices to fixed-field instrumentation systems that transmit signals to a central facility for logging, analyzing, and storing data.

*Product or manufacture identification shown in the figures does not imply endorsement by the Federal Water Pollution Control Administration.

Selection of Parameters and Output

Instruments can facilitate the collection of large amounts of data at closely spaced time-intervals and can be used advantageously for a variety of purposes. However each situation should be examined critically to determine if a need for instrumentation really exists. For example, many physical and chemical characteristics of a surface water remain relatively constant, or change slowly. Laboratory analysis of periodic grab samples often provides sufficient information for such parameters. Conversely, a critical water quality parameter, such as dissolved oxygen, may vary under certain conditions from an acceptable to a nonacceptable value in a short time. In general, instrumentation should be applied only to those situations where the parameters represent significant water quality changes over short periods.

The kind of output needed for water quality instrumentation depends on the type of study and the program requirements. For a given situation in short-term field survey work, a portable instrument with indicating meter may be the most practical equipment. However, if an instrument with an analog chart recorder would facilitate the collection of data, it should be selected only if the added cost, increased weight, and greater complexity of the system is compensated by savings in manpower and more effective representation of the needed information in graphic form. Where a large quantity of data is collected for automatic analysis, consideration should be given to output in digital form for the most efficient processing and storing for future retrieval.

Determination of Amount and Accuracy of Data

After the need for instrumental measurement of specific water quality parameters has been established, the duration of the data-collection period and the amount of data required should be determined. The instrument system may be capable of providing either continuous or frequent-interval recording. Frequently information collected from a fixed-monitoring location in a river is not needed on a continuous or even a several-minute-interval basis.[10] Usually sampling at thirty-minute, one-hour, or two-hour intervals will provide sufficient data to indicate significant changes and for storage records. If more data than needed are collected, the cost of handling, analyzing, and storage can nullify many instrumentation benefits.

To ensure accuracy of the data to be considered, very thorough planning is important. Except perhaps for reconnaissance surveys, a portable system should provide data as accurate as that obtained with a correctly operated fixed-station system, even though the latter normally has the advantage of shelter, protection from vibration, and routine calibration. The accuracy of all instrumented data should conform at least with that specified in **Standard Methods for the Examination of Water and Wastewater.**[11] To achieve this standard of accuracy with field instrumentation requires special precautions in calibration, operation, and maintenance. Since it may not be economically feasible, in some cases, to obtain the desired accuracy, the probable error of such collected data should be recognized.

Types of Instrumentation

Instruments for water pollution surveillance may be classified broadly for **laboratory** or **field** use. Laboratory instruments, such as colorimeters, spectrophotometers, and gas chromatographs, serve extremely important functions in the measurement of water quality characteristics of grab samples and are well documented in the literature.[12] The following material deals primarily with portable equipment and fixed-instrument systems used in field survey work and for continuous surveillance of water pollution parameters.

Portable instruments satisfactory for measuring such parameters as temperature, pH, conductivity, and dissolved oxygen[13, 14, 15] are available with probe or electrode sensors and indicating meters. **Figure 2** shows a battery-operated electronic thermometer with a thermistor sens-

ing element and marked cable to measure water temperature at various depths. A lightweight portable pH meter with manual adjustment for temperature compensation is illustrated in **Figure 3.**

Field measurement of conductivity, or of specific conductance, may be performed with a portable meter of the Wheatstone bridge type. The meter shown in **Figure 4** requires manual temperature compensation. Models with built-in thermistors for automatic temperature compensation are available.

A multiparameter portable instrumentation system for the measurement of dissolved oxygen and temperature is shown in **Figure 5.** This system uses a specially designed polarographic probe with semipermeable membrane for fast and accurate sensing of dissolved oxygen. The probe may be obtained with a built-in thermistor for convenient temperature measurement; it is also available with automatic temperature compensation for direct electronic readout of dissolved oxygen in milligrams per liter. Several probe-type sensors may be combined in a submersion assembly and connected by cable to an indicating or recording instrument, or to both. A four-element submersion probe assembly and multipoint strip-chart recorder for field measurement of dissolved oxygen, conductivity, temperature, and pH is illustrated in **Figure 6.** This system requires 120V, 60-cycle AC power, which can be furnished by a portable generator.

A semiportable water quality monitor, which measures water level in addition to dissolved oxygen, conductivity, pH, and temperature, is shown in **Figure 7.** This monitor requires 120V, 60-cycle AC power. Water is pumped from the stream to sensors located in the monitor assembly. The data for each parameter are recorded on separate strip charts.

Continuous surveillance for water pollution in a river or estuary generally requires sensing of selected water quality parameters at a fixed representative sampling site. Sensors may be placed in the stream for transmitting electrical signals to receiving instrumentation in a nearby shelter. However, operation and maintenance are facilitated if the entire instrumentation sys-

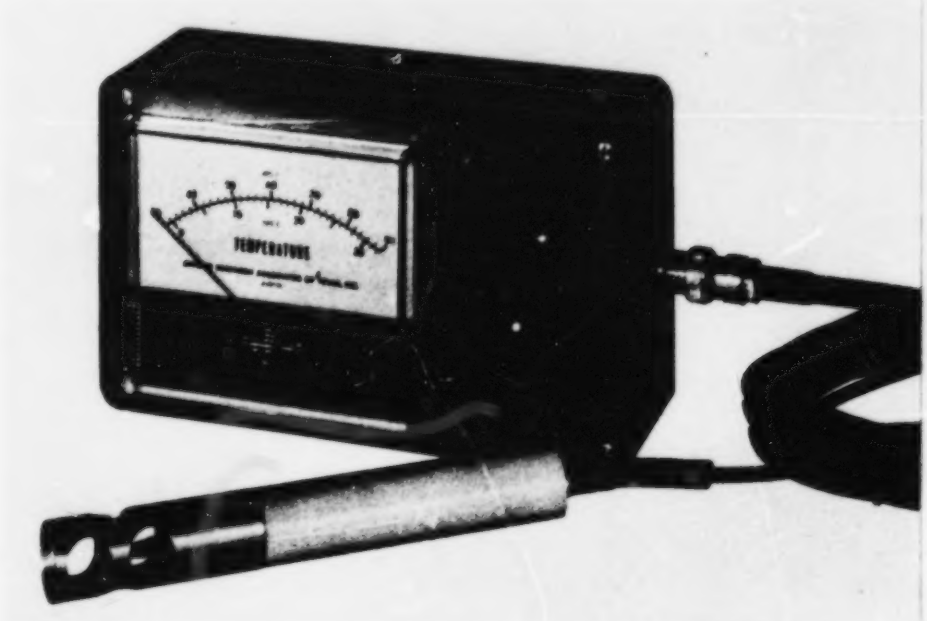


Figure 2. Portable electronic thermometer for measuring water temperatures at various depths.

Figure 3. Lightweight portable pH meter for field use.

Figure 4. Portable battery-operated conductivity meter.

tem is installed in a building where a continuous flow of water is pumped to the sensors. A satisfactory location may sometimes be found at a water treatment plant, an electric power generating station, or an industrial facility using river water. If such facilities do not exist at needed sampling points, a pumping system and an equipment shelter with electrical power must be provided.

Practical sensors of the probe type are available for measurement of temperature, pH, conductivity, dissolved oxygen, and dissolved chlorides. Sensors for other water quality parameters are in various stages of research, development, and field evaluation.

A number of variables useful in water pollution surveillance can be measured from grab samples in the laboratory[15] with automatic chemical-analysis systems. **Figure 8** shows the components of such an automatic analytical system arranged in use sequence. The sample and reagents are drawn automatically by a proportioning pump through plastic tubing, mixed, dialyzed or filtered, or both, and diluted and heated as required for specific tests. The test reaction usually involves color for automatic evaluation by colorimeter and potentiometric chart recorder. Such analyses as alkalinity, hardness, nitrate, ABS, sulfate, and iron are performed effectively with this type of automatic system. At the present stage of development, such systems are capable of short periods of unattended operation.

Field application of automatic analytical systems in station wagon and survey boat for ammonia-nitrogen and phenol determinations has been made by the Delaware Water Pollution Commission.[17] The Division of Pollution Surveillance is promoting the development of automatic systems compatible with sensor-type instrumentation for fixed-site field use. Specifications for such systems are in preparation.

During the past decade microbiologists have been studying radioactive carbon techniques[18, 19]

Figure 5. Oxygen analyzer with temperature thermistor for laboratory and field use.

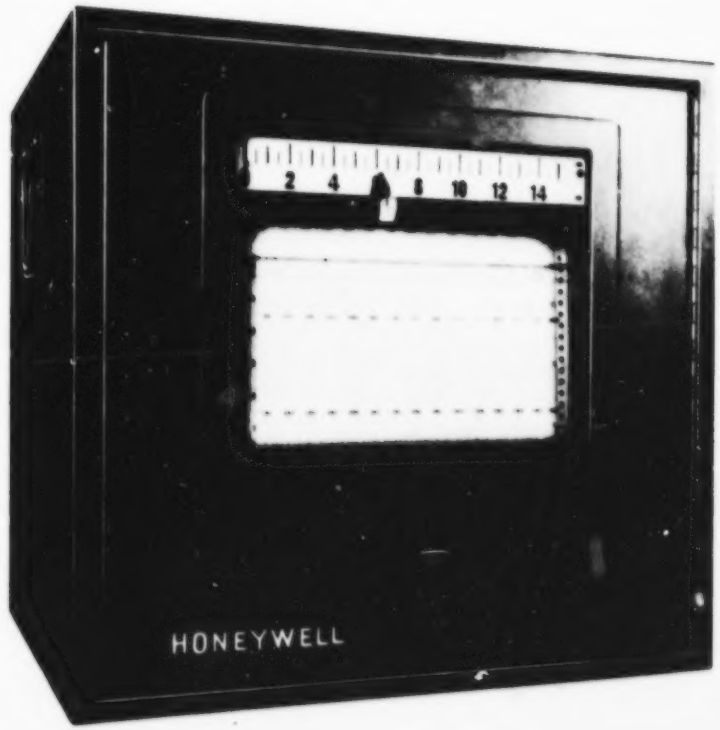
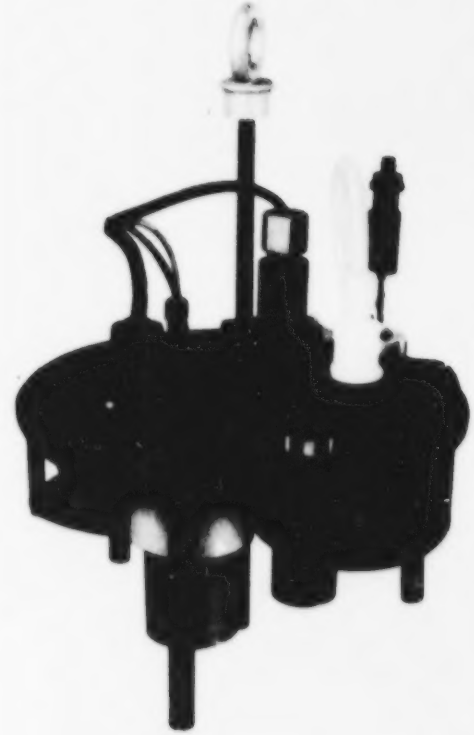


Figure 6. Left, multipoint recorder mounted in a modular portable case for recording four points when the four-element submersion probe is used.



Right, four-element submersion probe-assembly, with covers removed, for measuring dissolved oxygen, conductivity, temperature, pH.

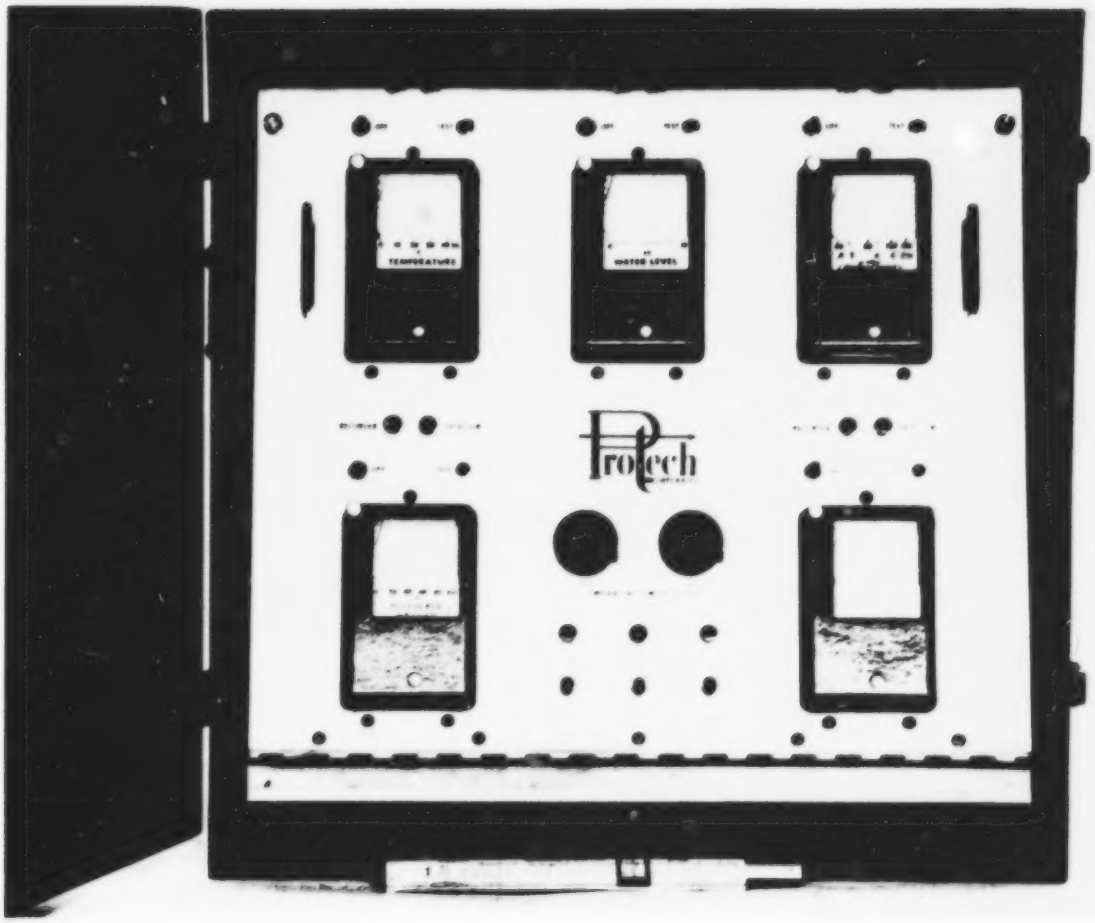


Figure 7. Semiportable water-quality monitor with separate strip-chart recorders for each parameter.

Figure 8. Components of an automatic chemical-analysis system.

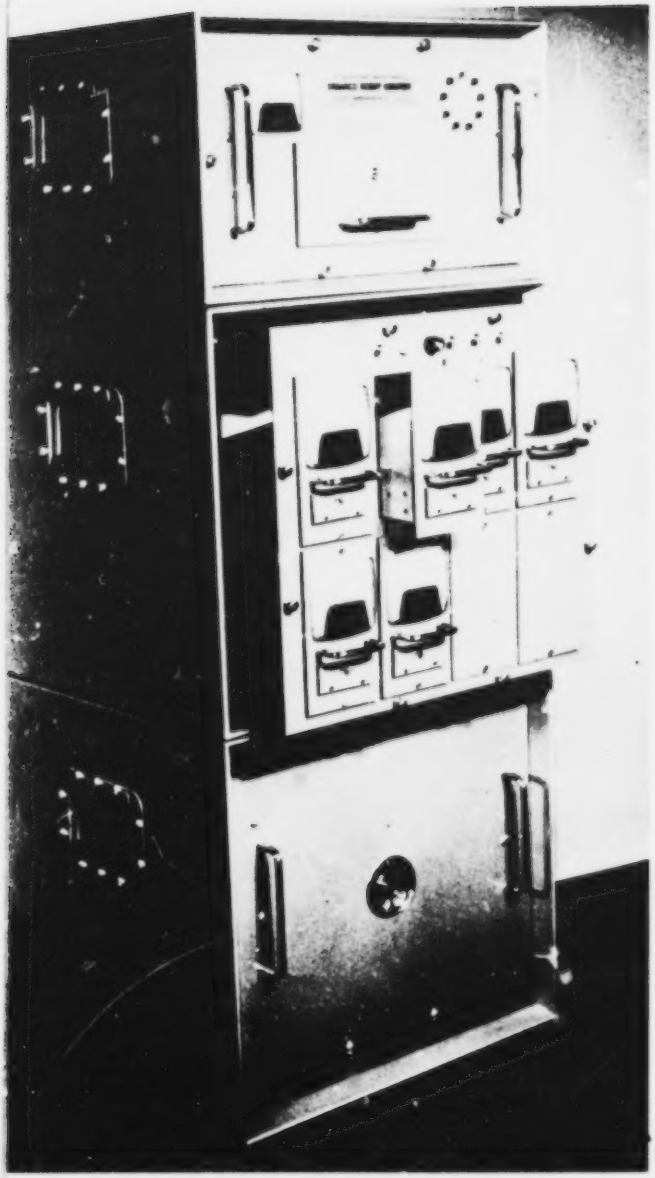


Figure 9. ORSANCO Robot Monitor unit with telemetering capability.

for development of a rapid indicator of bacterial pollution in water. Although problems still exist, the studies give promise of eventual development of a small sensor, using the radioactive carbon method, for automatic measurement of coliforms at remote stations. The possibility also exists that other biological indicators associated with plankton and algae may in the future be measured by automatic devices for pollution surveillance.

Expandable Integrated Data Acquisition System

The concept of an integrated automatic instrumentation system for monitoring water quality in a river basin was first explored and applied by the Ohio River Valley Water Sanitation Commission.[20] A prototype* of the "ORSANCO Robot Monitor" was placed in operation in September 1960. This instrumentation system used multiple electrode sensors and analyzers in modular packages for integrated recording and transmitting water quality data, and monitored temperature, pH, conductivity, dissolved oxygen, chloride ion, oxidation-reduction potential, and solar radiation. By June 1962, ORSANCO had six transmitter-type and five strip-chart recorder-type monitors in operation. The signals from the transmitter units were telemetered to Cincinnati for automatic recording on punched paper tape as well as for typing on a tabulation sheet. **Figure 9** shows a transmitter-type ORSANCO monitor.

A brief review of instrumentation for water quality determination, which includes an introduction to several integrated water-quality instrumentation systems, has appeared in the literature.[21] This review describes the flexible modular-design concepts for an expandable integrated water-quality data-acquisition system developed through laboratory and field studies, and details the specifications[22] first issued March 1963 for competitive procurement. The system was designed for continuous measurement of

*Designed by the Engineering Specialties Co. (now the Schneider Instrument Co.), Cincinnati, Ohio.

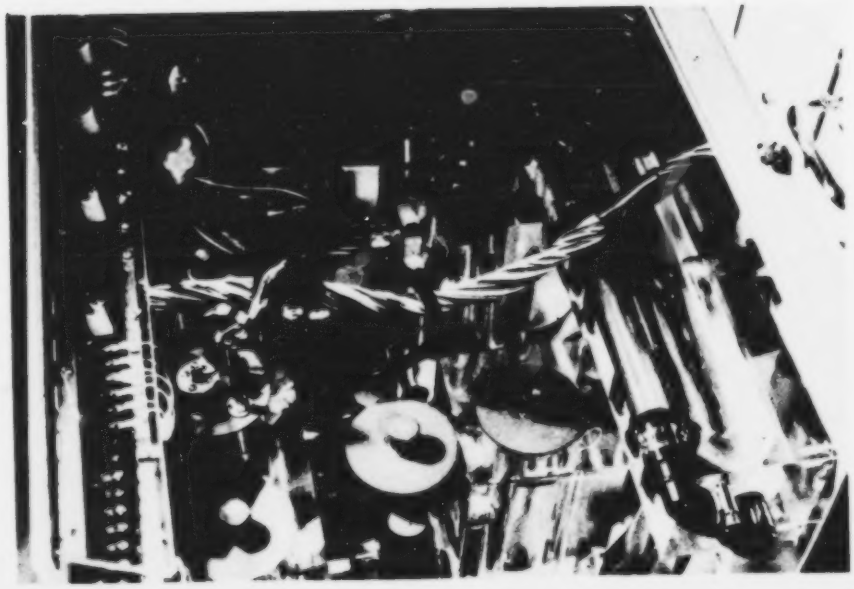


Figure 10. Pull-out drawer compartment with individual flow cells for sensors.

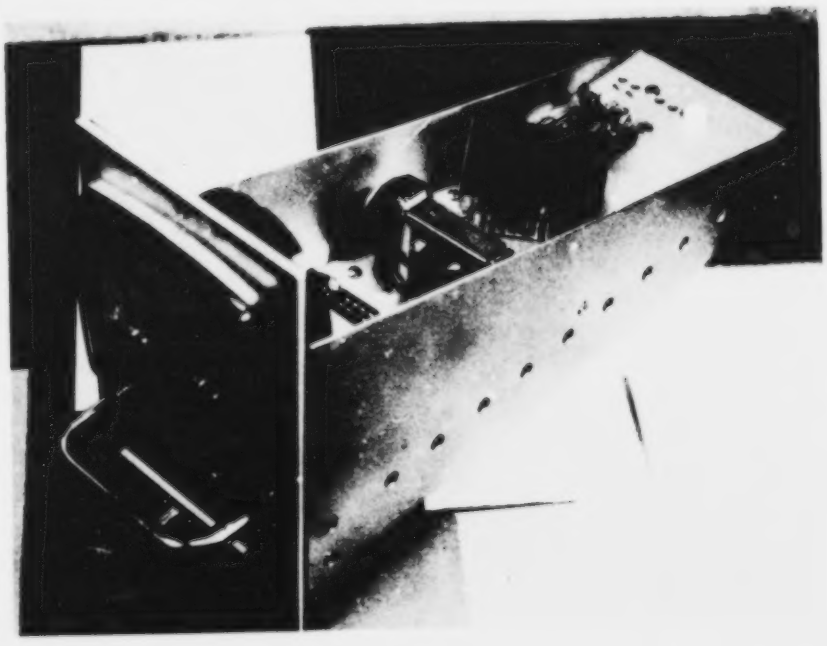


Figure 11. Modular plug-in analyzer with solid-state electronic components.

pH, conductivity, dissolved chlorides, dissolved oxygen, temperature, turbidity, and solar radiation intensity. For convenient operational checks and maintenance, the sensors are located in a single pull-out drawer compartment with individual flow cells, as shown in **Figure 10**. Analyzer components for each parameter are modular plug-in units (**Figure 11**) utilizing solid-state electronic circuits. This design provides a flexible system that is easy to maintain and repair.

The analog signals of this system are recorded on a multipoint strip chart. To facilitate storage and analysis, these data also are recorded in digital form unless a chart form only is needed. **Figure 12** shows an eight-channel paper-tape compartment fabricated for application in accordance with specifications.[23] When this tape has received the digital punching representing the raw data, it constitutes the input to the electronic computer.

Where several monitoring stations are located on a river system, it may be desirable and economical to transmit data to a central facility for controlled automatic recording in digital form on paper tape and on typewritten output log-sheet. Telemetry of data enables prompt detection of water quality changes and malfunctioning of the remote monitoring stations. The specifications prepared for two basic telemetering systems and for a central data-logging facility intended to be the nucleus of a 10-station water pollution surveillance system illustrate the magnitude of detail required in developing this equipment.[24] **Figure 13** shows the central logging facility for the Potomac River water pollution surveillance system located at the Federal Water Pollution Control Administration headquarters in Washington, D.C.

A digital record of water quality data is necessary if convenient analysis and storage of pertinent information are important. An analog strip chart may provide a useful temporary record of parametric measurements and facilitate the checking of the monitor's performance, but it is cumbersome and generally unsatisfactory for analysis of data. There are instances where statistical analyses of data are not required, and a strip-chart record obviously will suffice to show where measurements fall below or above established criteria.

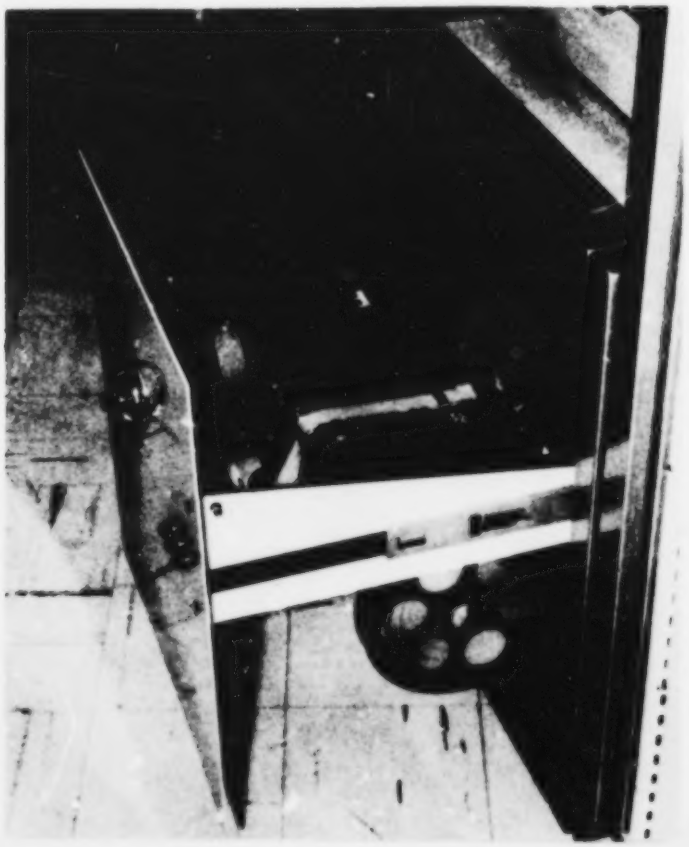


Figure 12. Pull-out compartment with 8-channel punched paper-tape recorder.

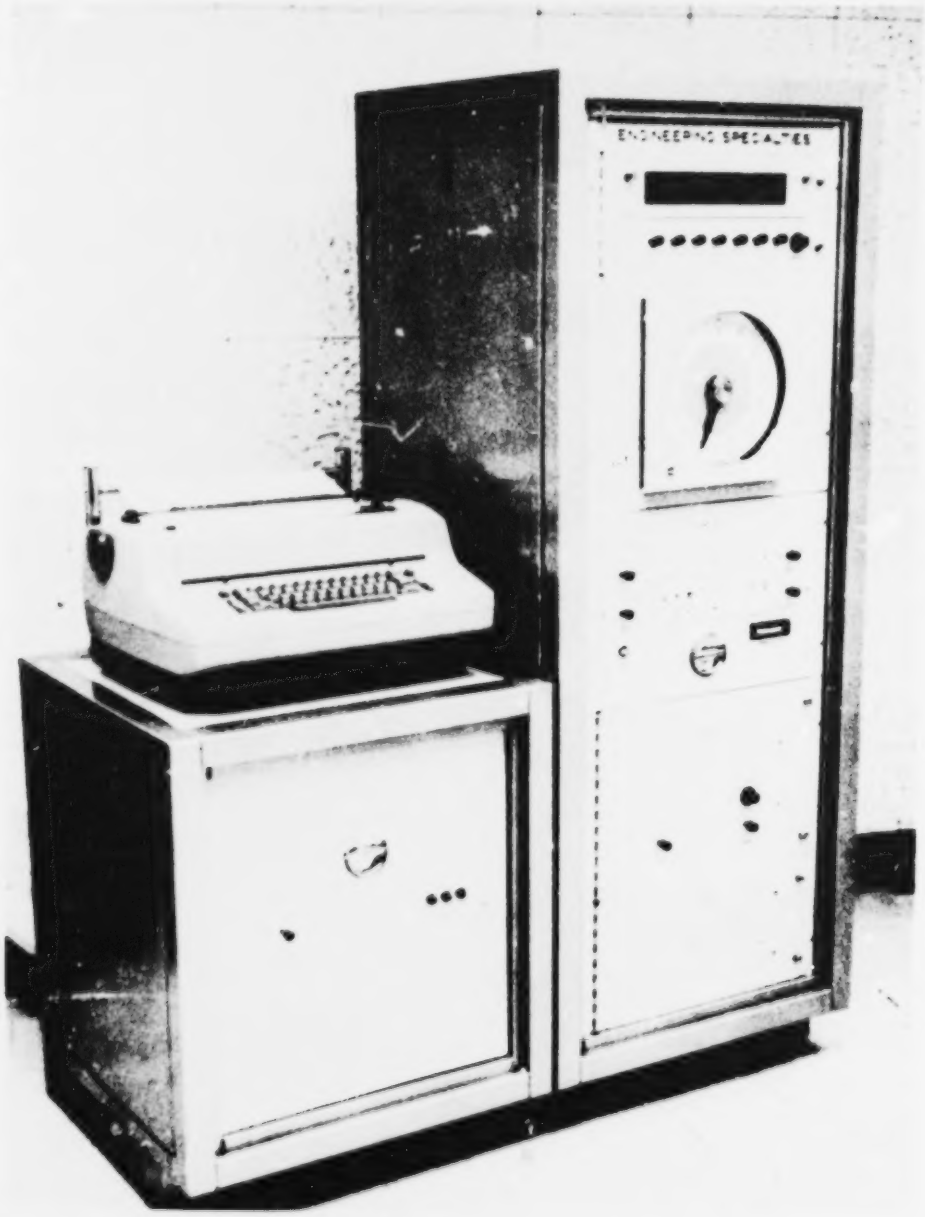


Figure 13. Central logging facility for Potomac River Water Pollution Surveillance System.

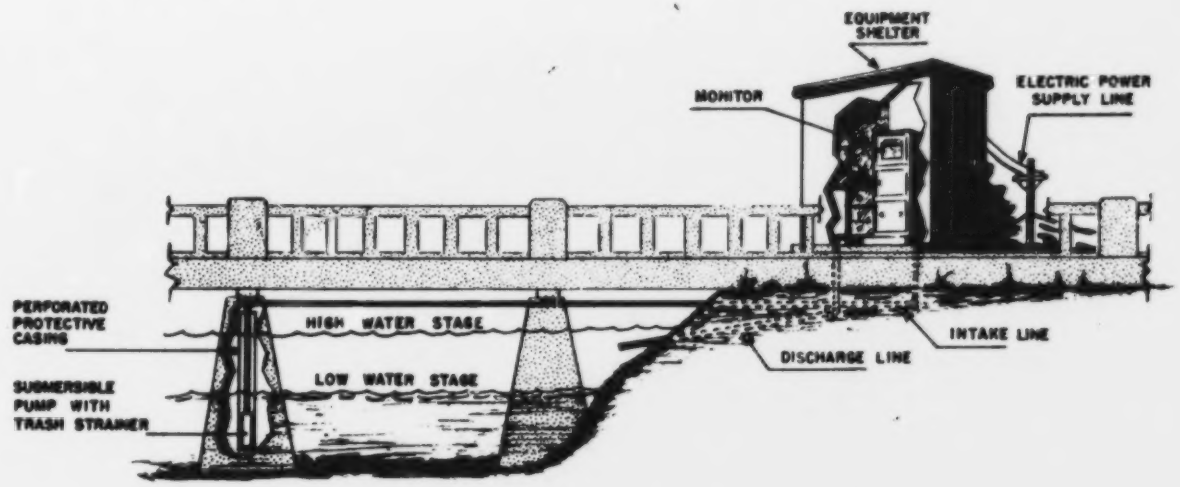


Figure 14. Schematic sketch of an automatic water-quality monitoring facility at a bridge.

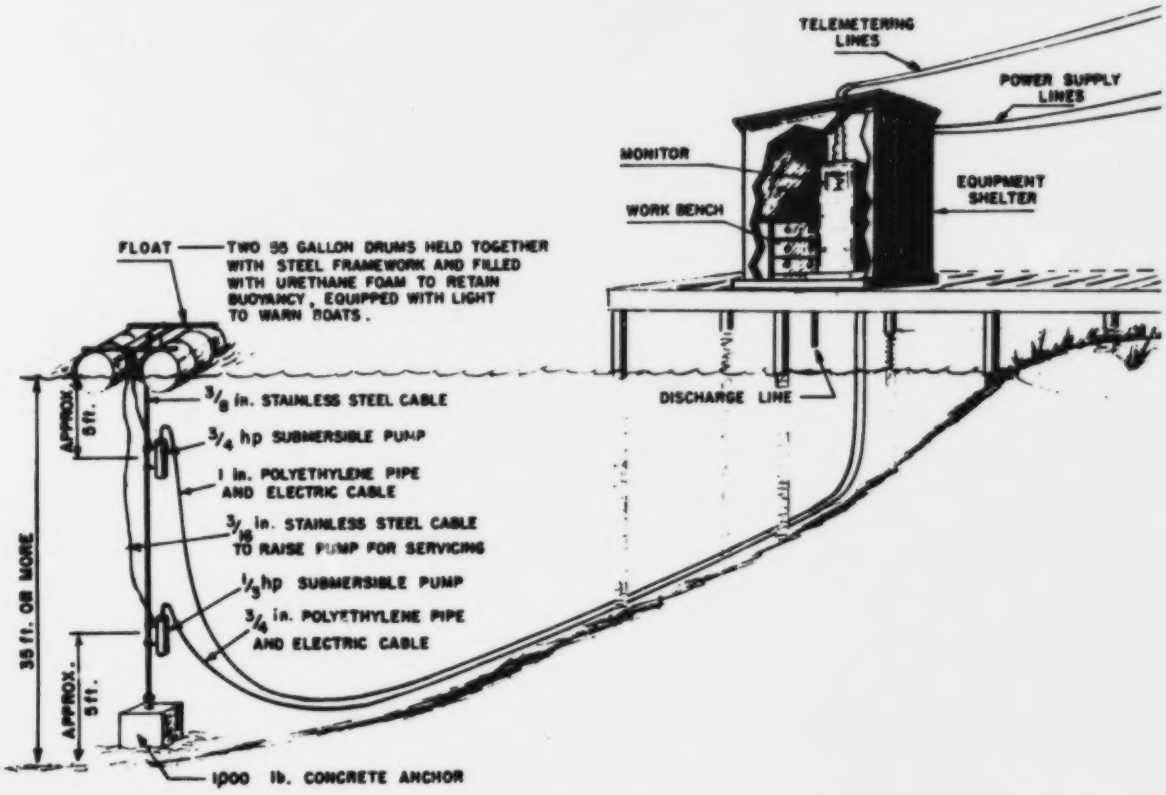

TELEMETERING LINES
POWER SUPPLY LINES
MONITOR
WORK BENCH
EQUIPMENT SHELTER
FLOAT
TWO 55 GALLON DRUMS HELD TOGETHER WITH STEEL FRAMEWORK AND FILLED WITH URETHANE FOAM TO RETAIN BUOYANCY, EQUIPPED WITH LIGHT TO WARN BOATS.
DISCHARGE LINE
APPROX. 5 ft.
3/8 in. STAINLESS STEEL CABLE
3/4 hp SUBMERSIBLE PUMP
1 in. POLYETHYLENE PIPE AND ELECTRIC CABLE
3/16 in. STAINLESS STEEL CABLE TO RAISE PUMP FOR SERVICING
1/3 hp SUBMERSIBLE PUMP
3/4 in. POLYETHYLENE PIPE AND ELECTRIC CABLE
35 ft. OR MORE
APPROX. 5 ft.
1000 lb. CONCRETE ANCHOR

Figure 15. Schematic sketch of a two-level monitoring facility.

Planning a Sampling Facility

The objectives for monitoring a specific river, lake, or other body of water should be firmly established before sampling sites are selected, and they should be based on sound sanitary engineering stream-survey principles. Intake systems for water treatment plants, power plants, and factories, although sometimes conveniently located for sampling, do not always provide representative samples. Dams, bridges, wharves, piers, and other structures frequently serve as suitable sampling locations. Again, the actual sampling point, or points, should be carefully selected if useful water quality data are to be obtained. **Figure 14** indicates schematically how a monitoring facility with a single intake can be installed at a bridge. Note that electrical power, a submersed pumping system, and an equipment shelter are required. If existing structures are not satisfactory for sampling, an accessible site affording representative samples, preferably near electric power supply lines, should be located.

In tidal estuaries and other situations where water characteristics at upper and lower levels may be quite different, multilevel sampling should be considered. **Figure 15** shows a two-level intake facility where tidal fluctuation is normally less than 5 feet. Two submersible pumps are supported by an anchor-cable-buoy system at the edge of the river channel. The intake of the upper pump is approximately 5 feet below the surface of the water and the intake of the lower pump is about 5 feet above the river bottom. The water is pumped to a small prefabricated metal structure which houses the automatic instrumentation system. In such installations it is usually desirable to provide a dual set of flow cells and parameter sensors — one set for each pump output — rather than to arrange for automatic alternation of the pump outputs to a single set. If only a single set were provided, the response* of the sensors might be too slow to pick up the wide differences in quality values which often exist at various water levels.

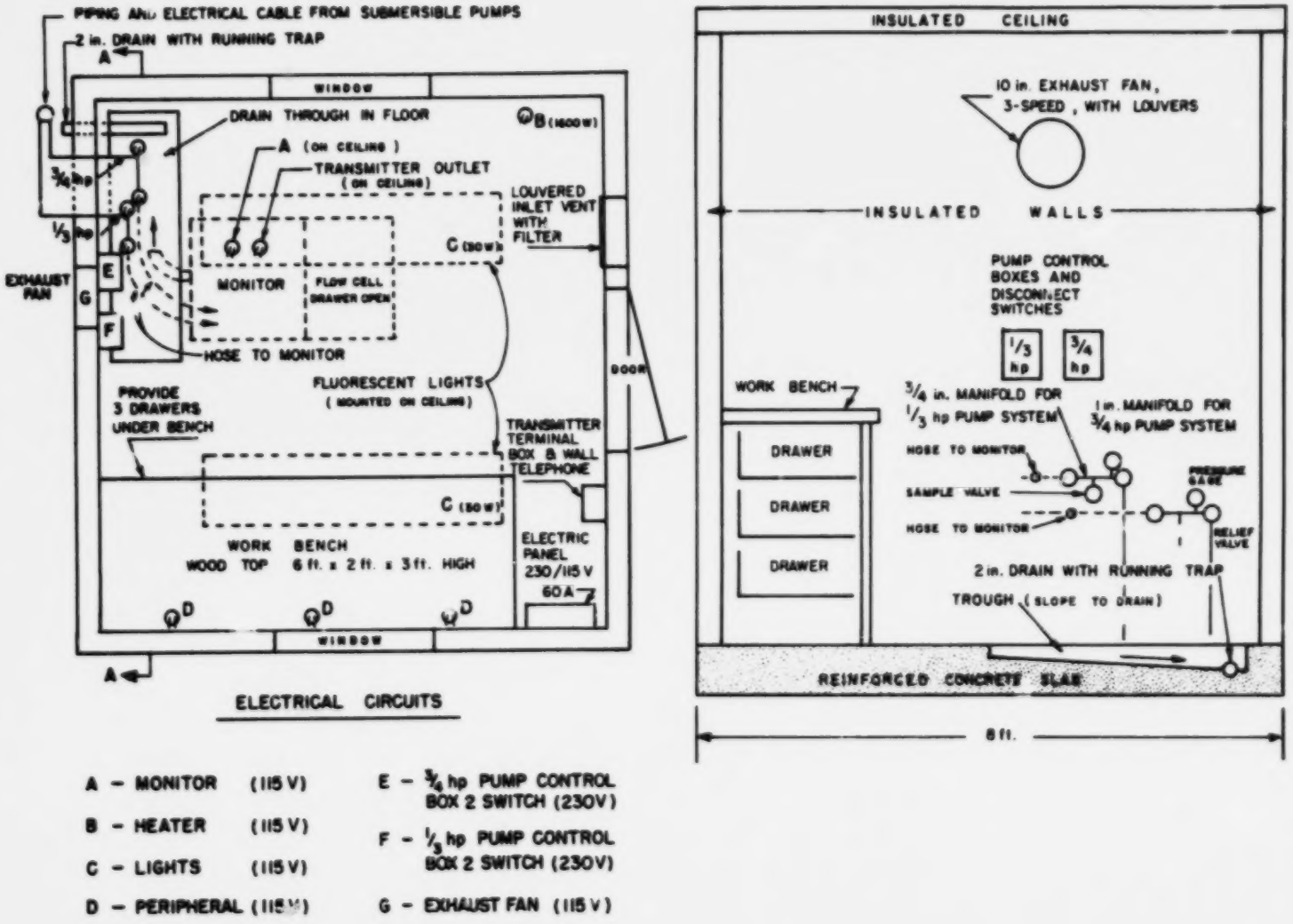
Figure 16 shows a proposed equipment layout for a two-level sampling facility on the Potomac River at Indian Head, Maryland. The layout design provides adequate supply of electric power for the monitor, pumping systems, lighting, heating, and ventilating. It calls for erection of a prefabricated structure on a reinforced concrete slab floor with a built-in drain trough for waste water, and insulated walls and ceiling for temperature control. It provides a thermostatically controlled electric heater to maintain above-freezing temperature in winter, and good lighting and a workbench with drawer space to facilitate calibration and maintenance of the instrumentation system.

Submersible pumps of the positive displacement type with stainless steel rotor and synthetic rubber stator are generally used for intake systems. These pumps do not change the character of the water and they perform satisfactorily with water containing silt, sand, and other particulate matter.

Figure 17 illustrates a submersible pump and stator with cut-out section to show the rotor. A flexible coupling connects the rotor to the motor. Large particulate matter and trash in the water being sampled are prevented from entering the pump by a stainless steel strainer which completely encloses the pump, as shown in **Figure 18.** Shown also are attaching devices for upper and lower pumps supported by an anchor-cable-buoy system.

Cost of the sampling facilities, exclusive of electronic equipment, shown in **Figures 14 and 15** ranges from less than $3,000 to over $6,000, depending on the site, availability of electrical power and telemetry lines, single or multilevel sampling, and specific situation factors. Under favorable conditions, an equipment shelter as shown in **Figures 16** — with workbench and facilities for lighting, heating, and ventilating — can be installed for approximately $2,500 including labor. Cost of the two-level pumping and buoy-cable-anchor systems illustrated in **Figure 15** is estimated at $2,000. Funds must be provided for inspection, servicing, and repair, and for periodic replacement of pumps. Except for special circumstances, facilities similar to those described are required for satisfactory operation and maintenance of automatic monitoring stations. Costs of instrumentation systems are discussed on page 17.

*Often referred to as transient response.



ELECTRICAL CIRCUITS

A – MONITOR (115 V)
B – HEATER (115 V)
C – LIGHTS (115 V)
D – PERIPHERAL (115 V)
E – 3/4 hp PUMP CONTROL BOX 2 SWITCH (230 V)
F – 1/3 hp PUMP CONTROL BOX 2 SWITCH (230 V)
G – EXHAUST FAN (115 V)

Figure 16. Proposed equipment layout for monitoring facility at Indian Head, Maryland.

Calibration, Operation and Maintenance

Instrument systems should be carefully calibrated when installed in the field, using standard analytical methods or proven reference instruments. Following installation, systems should be checked periodically for performance, and recalibrated when necessary. To assure valid data, calibration of each parametric system should cover the entire range of measurements as changes occur in water quality. Since temperature changes affect parametric systems, such as dissolved oxygen, pH, and conductivity, these systems must be temperature-compensated.

To maintain continuous operation within defined limits of accuracy, most sensors require periodic cleaning. Although acceptable data can sometimes be obtained over long periods of operation without inspection or cleaning of probes, accurate data can be assured only with a weekly operational check and sensor cleaning by a trained technician. Functional troubleshooting should be performed by personnel with engineering or scientific training. Electronic engineering backup from a central facility may be required to solve difficult field problems. In some cases, contracts can be arranged with a manufacturer to cover whatever degree of maintenance is desired.

Handling, Automatic Processing, and Evaluation of Data

The very large amount of data which can be produced by automatic water-pollution-control monitors must be handled by modern data-processing systems if their most effective use is to be realized. A basic system, STORET[25, 26, 27] (STOrage and RETrieval), was designed and built around the computer for the handling, processing, storage, and retrieval of water-pollution control data. The STORET system accepts data collected by Federal, State, and local agencies in a variety of formats, with each variable of interest assigned a five-digit parameter num-

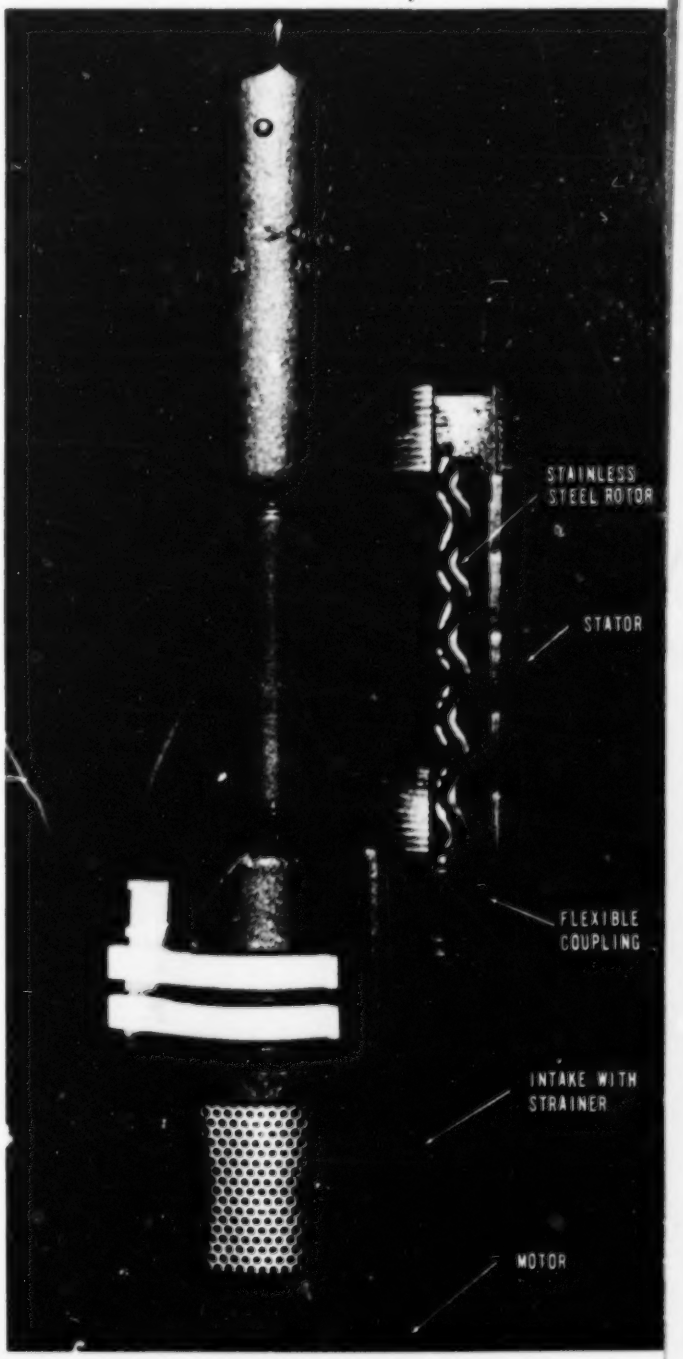


Figure 17. Submersible pump and stator with cut-out section to show rotor.

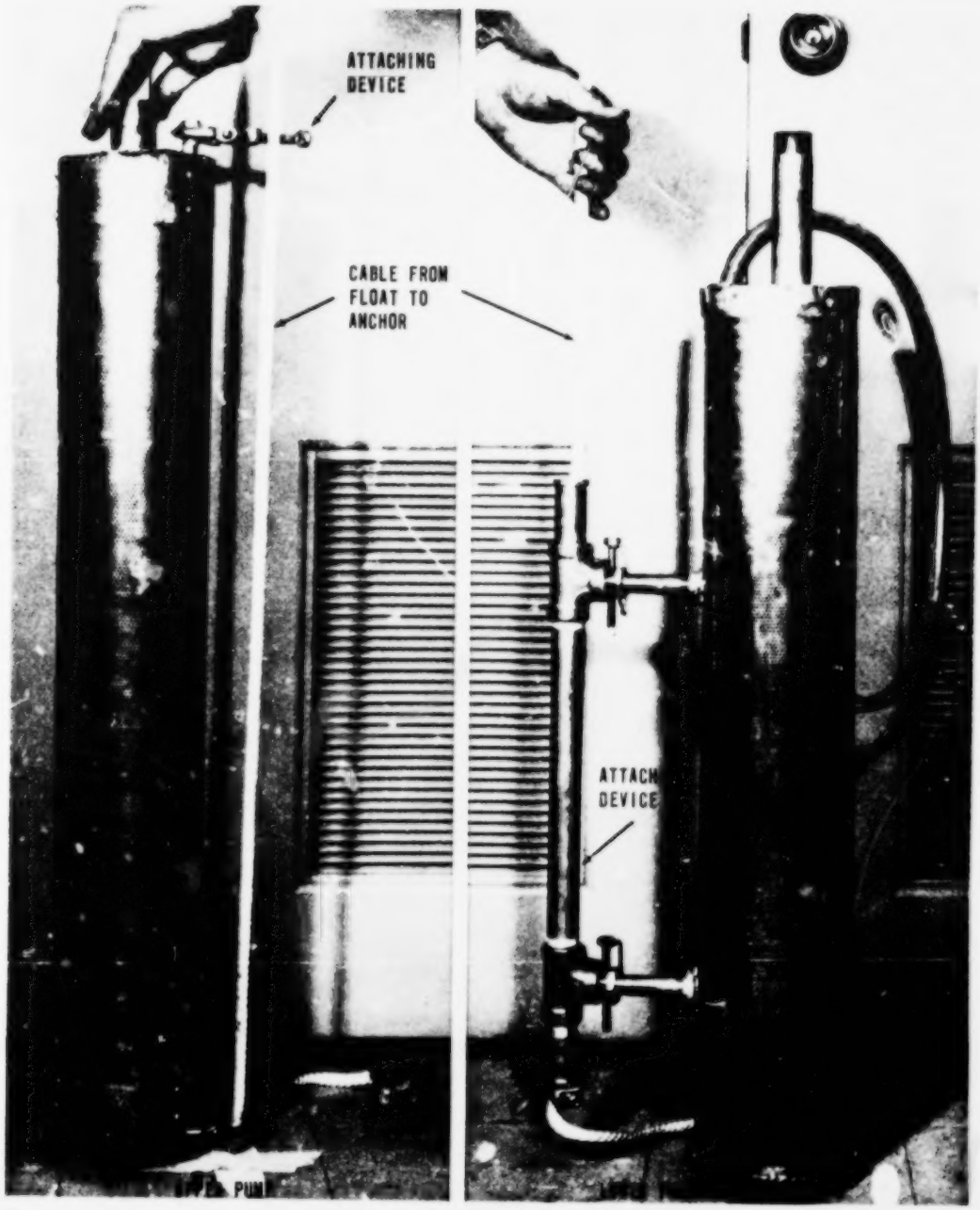


Figure 18. Submersible pumps enclosed in perforated stainless steel strainers with devices for attachments to cable.

ber.[20] The large volume of data supplied by automatic water quality monitors requires special handling in STORET to avoid overburdening the system for processing data from conventional sources.

Evaluation of water quality data from a stream surveillance program generally requires a variety of analyses. Daily, weekly, or monthly tabulation of average, maximum, and minimum values of parametric measurements may suffice. Where instrumentation systems are employed, a more complete analysis of data, with periodic reporting of the pertinent information, is usually needed. Subsequent additions and modifications to the STORET system have been made for handling data from automatic monitors.[20] A statistical analysis program,[20] a stream loading program, and other specialized programs also have been developed,[21] affording wide flexibility of data processing, analysis, and reporting to users of this system. For water quality management purposes, narrative reports[22] with summary information in concise graphical form are particularly helpful.

Instrumentation Costs

The cost of instrumentation for water pollution surveillance varies widely according to program objectives. It is affected by the variables required, such as number of parameters, required accuracy, reliability, flexibility, modularity, application, and data use.

A portable survey meter with acceptable accuracy for measuring a single parameter such as temperature or pH costs $100 to $200. Satisfactory survey instruments for sensing and indicating the two parameters of dissolved oxygen and temperature are available for approximately $600. Production models of integrated systems that can measure from three to eight parameters, with a single output mechanism such as an analog strip-chart recorder, cost $4,000 to $12,000. Addition of a transmitter increases the cost by about $2,500.

Where data are transmitted to a central facility, approximately $30,000 should be added for instrumentation for automatic data logging and digital output on 8-channel punched paper tape. This $30,000 can be prorated over the number of monitoring stations served; e.g., with ten stations, the cost of the central equipment per station would be $3,000.

Additional costs will depend largely on operational needs, such as personnel costs for installation, subsequent weekly or more frequent maintenance visits by qualified technicians, secondary backup by electronic specialists, travel, pumping, land use, shelter requirements, and administrative overhead.

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